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GENERAL DYNAMICS | CONVAIR

Report No. 8926-002

Material - Titanium Alloy - Ti-13V-11Cr-3Al
(B-120-VCA)

Strength and Driving Characteristics of Cold Headed Rivets

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Abstract

Three-sixteenths inch diameter cold headed flat-head Ti-13V-11Cr-3Al (B-120-VCA) titanium alloy rivets were fastened into 0.043 inch thick 4130 steel strips heat treated to 180,000 to 200,000 psi ultimate tensile strength. Ultimate shear strengths of 109,000 to 100,000 psi were developed by gun driving and squeezing cold headed rivets and by gun driving cold headed and annealed rivets. Severe cold working during cold heading caused rivet breakage during driving, but this was relieved by vacuum annealing prior to driving.

Reference: Stier, H., Bergstedt, P. W., Turner, H. C., "Cold Headed Rivets of B-120-VCA Titanium Alloy," General Dynamics/Convair Report MP 58-262, San Diego, California, 24 November 1958 (reference attached).

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A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO

STRUCTURES & MATERIALS LABORATORIES

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COLD-HEADED RIVETS OF B-120-VCA TITANIUM ALLOY

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OBJECT:

To determine the strength and driving characteristics of cold-headed rivets of B-120-VCA titanium alloy.

CONCLUSION:

1. Lapped joints fastened by cold-headed B-120-VCA rivets with protruding flat heads have these strengths: (when tested at room temperature in joints in hardened 4130 steel sheet)

	Cold-Headed Rivets		Cold-Headed & Annealed Rivets
	Gunned	Squeezed	Gunned
Ultimate shear, psi	109,600	109,400	110,400
Ultimate tensile, psi	59,400	62,000	96,000

2. The cold-headed rivets have a severely deformed grain structure at the base of the manufactured head which causes the rivets to fail by snapping off the manufactured head when loaded in shear or tension.

3. The cold work effects (mentioned in 2) can be relieved by an annealing treatment of the cold-headed rivets before driving (vacuum anneal at 1450°F., 30 min., AC).

4. The strength of gunned rivets which have not been vacuum annealed before driving depends upon who's behind the gun as shown below:

	Ultimate shear, psi	Ultimate tensile, psi
G-6 gun, Riveter #1	76,700	15,200
G-6 gun, Riveter #2	109,600	59,400

5. Corrosion in 7075-T6 Alclad is accelerated by the bare B-120-VCA rivets.

6. A load of 11,200 pounds is required to squeeze a 1/4 in. diameter head on a 3/16 in. diameter B-120-VCA rivet.

TEST SPECIMENS:

The rivets provided for this test were 3/16 in. diameter flat-head rivets of B-120-VCA titanium which had been cold-headed in the annealed condition. The manufactured heads had a fillet of .008 in. radius between the head and the shank. Rivet shanks protruded 1.14 diameters before driving in the sheet combinations of this test.

TEST SPECIMENS: (Continued)

The shear specimens were of the single lap-joint type with two tandem rivets spaced at 3/4 in. along the longitudinal center-line of the joint and with 1/2 in. of edge distance The sheet material was .063 in. thick 4130 steel strips, 2 in. wide, heat treated to 180,000 - 200,000 psi.

The tension specimens were similar to those of Figure 1 of ETL Report 9536 having a single rivet through two sheets of .063-in. thick 4130 steel, heat treated to 180,000 - 200,000 psi.

Two methods of driving of rivets were employed in fabricating the shear and tension specimens:

a) squeezing with a flat set in a pneumatic compression riveter, and

b) gunning with a flat set in a G-6 pneumatic rivet gun.

Rivets which cracked during driving were removed from rivet holes with a drill and punch. Driven rivets were inspected for cracked, off center, or tilted heads.

One group of rivets was vacuum-annealed (1450°F., 30 min., AC) after cold-heading and prior to driving. These rivets were sealed in a Vycor glass tube at a pressure of about 3 microns of mercury. The rivets were cleaned with alcohol and absorbent cotton before annealing.

Corrosion specimens had three driven rivets spaced at one inch along the longitudinal center line of .125" x 1 1/2" x 10" coupons of clad 7075-T6 sheet or 321 stainless steel sheet.

TEST PROCEDURE:

The shear specimens were pulled in a 60,000 pound Tinius-Olsen tensile machine at a maximum loading rate of 1000 pounds/min. A U-1 extensometer or an S-1 extensometer was used to measure the yield strength of the joint by recording a stress-strain curve from which the load corresponding to a permanent joint set of .005" could be determined. The curve was continuous and was intersected by an off-set drawn parallel to the straight-line portion.

The tension specimens were forced apart with a special fixture (described in ETL Report 9536) which produced a tensile load on the rivet. The fixture was loaded in compression at 1000 or 4000 pounds/min. in the 60,000 pound Tinius-Olsen machine.

The corrosion specimens were wiped with alcohol and placed in a salt spray cabinet for observation. The salt spray was operated in accordance with Federal Test Method Standard 151, Method 811.

RESULTS & DISCUSSION:

The results of Table I show the importance of proper gunning techniques and the beneficial effect of vacuum-annealing of rivets prior to gunning. The low strength of specimens gunned by Riveter #1 can be attributed to his unfamiliarity with the rivet material. Driving of the cold-headed B-120VCA rivets (no thermal treatment after cold-heading) requires a heavy manual force behind the G-6 gun. Riveter #1 used insufficient force with the G-6 gun and produced a driven head which was widest at the top. Properly gunned rivets have driven heads which bulge at mid-height.

Vacuum annealing of rivets after cold-heading and prior to driving not only improved the strength but also permitted easier gunning of the rivets. No heads cracked or snapped off during gunning of the vacuum-annealed rivets. (Four of the un-annealed manufactured heads snapped off while being gunned.) Most of the driven heads of annealed or un-annealed rivets were somewhat off-center however (not rejectable according to MPS-46.05-D).

The type of failure of the vacuum-annealed rivets which were tested in tension indicated that the cold work effects in the manufactured heads were completely relieved by the annealing treatment. Instead of snapping off when loaded in tension, the manufactured heads sheared along a surface parallel to the surface of the rivet shank. (Also, see ADDENDUM below.)

The load required to squeeze the protruding heads of the 3/16 in. diameter titanium rivets to .250± .007 in. diameter is given in Table II.

The corrosion specimen incorporating titanium rivets in clad 7075-T6 sheet was severely attacked after 250 hours in the salt spray cabinet. A heavy, grey, adherent scale covered the Alclad in areas up to one inch in diameter near each rivet. The corrosion specimen incorporating titanium rivets in type 321 stainless steel was slightly attacked after 400 hours in the salt spray cabinet. A small amount of rust appeared to be emanating from the crevices between the rivet heads and the stainless sheet.

ADDENDUM: Micro-sections through the manufactured heads showed a complete re-crystallization of the cold worked grains after vacuum annealing. (See Fig. 1.) The severely deformed grains were replaced by a new set of polygonal grains of approximately the same grain size & hardness as the non-deformed grains. The Rockwell C hardness in the deformed & non-deformed grains is given below:

	Hardness in deformed grains, Rockwell C *	Hardness in non-deformed grains, Rockwell C *
Cold-headed rivets	38 - 40	30 - 32
Cold-headed & vacuum annealed rivets	30 - 33	30 - 32

* Rockwell C converted from Knoop indentations with 1400 gram load.

NOTE: The data from which this report was prepared are recorded in Laboratory Data Book No. 3011.

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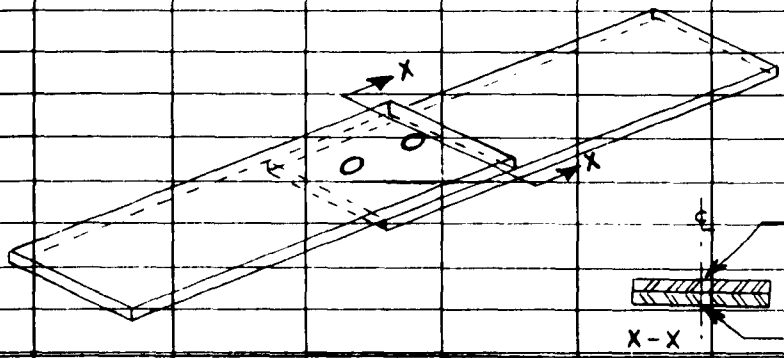
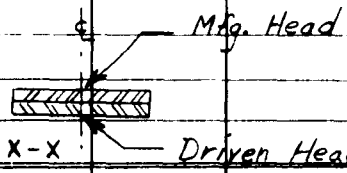
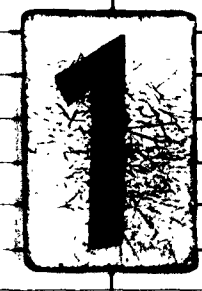
TABLE I. RESULTS OF TESTS OF RIVETED JOINTS INCORPORATING PROTRUDING HEAD B-120-VCA TITANIUM ALLOY RIVETS IN 4130 STEEL SHEET(g)

SHEAR TESTS OF RIVETED LAP-JOINTS

Identif.	Rivet Driving Method	Meas'd. Hole Diam., In.	Driven Head Diam., In.	Thermal Treatment of Rivets	YIELD LOAD #/rivet	ULT. LOAD #/rivet	ULT. STRENGTH psi.(d)	TYPE OF FAILURE(e)	Identif
1-1	Squeeze	.192-.194	.252-.254	NONE	2670	3075	105,500	1	X-1
2-2	" (a)	.193-.194	.252-.257	"	2895	3155	107,300	1&2	X-2
3-3	"	.193-.194	.248-.253	"	3115	3338	113,500	1	X-3
4-4	"	.191-.191	.254-.256	"	3003	3180	111,200	1	
				Avg.	2921	3187	109,375		
5-5	Gun(b)	.193-.193	.228-.248	NONE	--	2578	88,000	1	X-4
6-6	"	.193-.194	.243-.249	"	--	2743	93,300	1	
7-7	"	.191-.193	.242-.246	"	--	1595	55,200	1	
8-8	"	.191-.192	.247-.250	"	--	2023	70,200	1	
				Avg.		2235	76,675		
I	Gun(c)	.189-.190	.273-.277	NONE	2995	3155	111,300	2	II
II	"	.188-.189	.251-.264	"	2945	2985	106,400	1&2	III
III	"	.190-.190	.259-.278	"	3000	3295	116,300	2	
IV	"	.188-.188	.267-.274	"	2710	2890	104,200	1&2	
				Avg.	2913	3081	109,550		
N-5	Gun(c)	.190-.192	.270-.272	ANNEAL.	2745	3045	106,200	2	N-1
N-6	"	.189-.190	.268-.270	"(f)	2860	3160	111,500	2	N-2
N-7	"	.189-.190	.268-.285	"	2825	3200	113,400	2	N-3
				Avg.	2810	3135	110,367		N-4







(a) Chicago Pneumatic compression riveter CP-625.

(b) Gunned in Dept. 31 with G-6 pneumatic rivet gun - Riveter # 1.

(c) " " Plant 2 " " " " " - Riveter # 2.

(d) Based on measured hole diameter.

(e) See FAILURE NOTES at right.

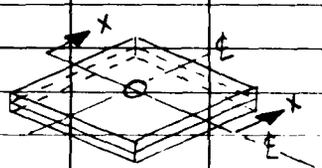
(f) Cold-headed rivets were vacuum annealed before driving (1450°F., 30 min., AC)

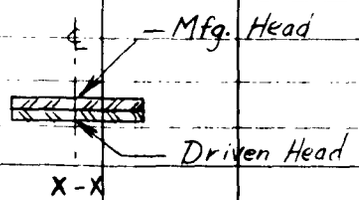
(g) Thickness .063"; heat treated to 180,000-200,000 psi. (R_c = 41.5-46.8).

FAIL

TENSION TESTS OF RIVETED JOINTS

Identif.	Rivet Driving Method	Meas'd. Hole Diam., In.	Driven Head Diam., In.	Thermal Treatment of rivets	ULT. LOAD #/rivet	ULT. STRENGTH psi.(d)	TYPE OF FAILURE(e)
X-1	Squeeze	.199	.243-.258	NONE	1500	48,200	1
X-2	" (a)	.192	.241-.253	"	1795	62,100	1&3
X-3	"	.193	.248-.257	"	2225	75,600	1&3
				Avg.	1840	61,967	
X-4	Gun(b)	.192	.248-.257	NONE	440	15,200	1
II	Gun(c)	.189	.278	NONE	2260	80,600	1
III	"	.189	.275	"	1070	38,200	1
				Avg.	1665	59,400	
N-1	Gun(c)	.190	.277-.286	ANNEAL.	2620	92,400	4
N-2	"	.189	.271-.291	"(f)	2720	97,000	4&5
N-3	"	.190	.260-.267	"	2790	99,000	4&5
N-4	"	.190	.271-.283	"	2710	95,700	4
				Avg.	2710	96,025	





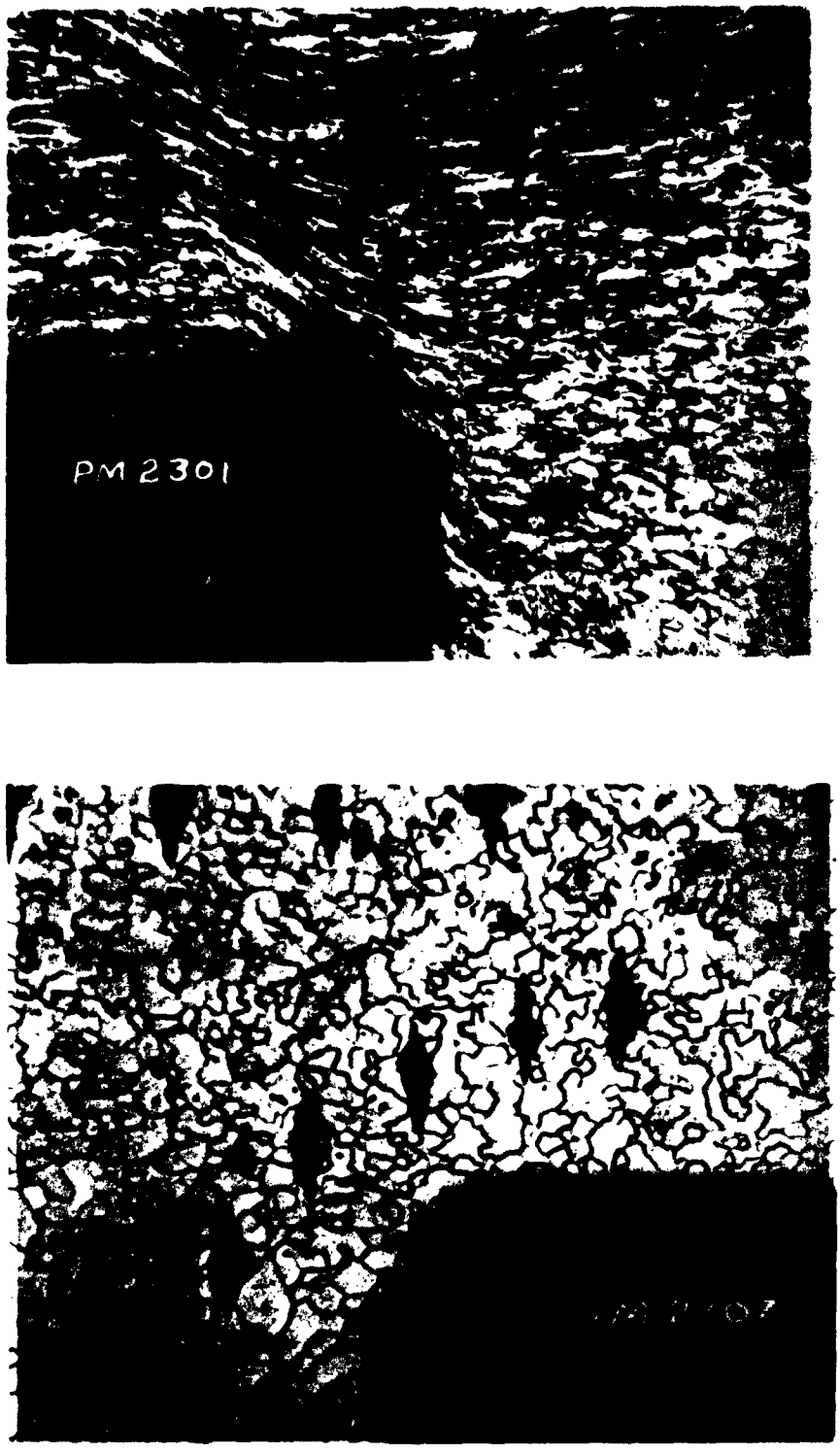
FAILURE NOTES:

1. Mfg. heads snapped off.
2. Rivet sheared in the shank along sheet interface.
3. Chipped mfg. head.
4. Shear thru mfg. head parallel to the surface of the rivet shank.
5. Partial tensile failure within mfg. head.

TABLE II.

RESULTS OF RIVET-DRIVING TESTS OF B-120-VCA TITANIUM RIVETS.

Identif.	Rivet Shank Diam., inch	Hole Diam., inch	Driven Head Diam., inch	Sheet Thk., inch	Sheet Mat'l.	Rivet Driving Method	Rivet Set	LOAD REQUIRED TO SQUEEZE RIVET HEAD TO 1 1/3 DIAM.
7075-T6								
#1	.1875	.191	.255	.125	7075-T6	Squeeze	Flat	11,000
#2	"	"	.258	"	"	"	"	11,500
#3	"	"	.264	"	"	"	"	11,250
321 ST. STL.								
#1	"	"	.256	"	ST. STL. 321	"	"	11,250
#2	"	"	.251	"	"	"	"	11,100
#3	"	"	.249	"	"	"	"	11,200
							Avg.	11,216



Microsections through the manufactured heads of rivets of B-120-VCA titanium alloy. TOP: Cold-headed. BOTTOM: Cold-headed & vacuum-annealed. (100-X. Kroll's etch.)

FIGURE 1.